

# **Ocean Response Coastal Analysis System**

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## **LONG-TERM GOALS**

The joint goal of the Naval Research Laboratory (NRL) and the Commander, Meteorology and Oceanography Command (CNMOC) is to develop a capability to describe diver visibility and vulnerability, and demonstrate how new, innovative technology allows a better 3D/4D representation of the optical field for Navy applications. The new technology that is explored in this research is the use of self-contained, small portable optical/ biological/ chemical moorings. These data will be used to validate and/or improve visibility and vulnerability estimates for operational scenarios.

## **OBJECTIVES**

The joint objectives of NRL and CNMOC in this program are to test and improve existing diver visibility and vulnerability algorithms using sensors that are to be incorporated onto the Ocean Response Coastal Analysis System (ORCAS). Sensors to be tested include a bioluminescence profiling package (University of Southern California at Santa Barbara) and the multi-angle scattering sensor and 20-channel multi-spectral absorption and attenuation meter (WET Labs, Inc.). The goal is to test and validate this new optical instrumentation and to apply the resulting data toward tailored optical products via the Naval Oceanographic Office (NAVOCEANO) to support Naval and Joint operations.

The development of ORCAS with its small autonomous profiling instrumentation will allow a more accurate 3D/4D representation of the optical field in realtime. However, algorithms that use the output of these instruments must be compared against a more complete optical set of measurements as well as actual diver visibility and vulnerability measurements. Thus, the project Gauging Littoral Optics for the Warfighter (GLOW) has joined the ORCAS team to collaborate to apply the developing profiler technology to specific military applications. The participation by the Navy in the ORCAS program is targeted toward several areas: 1) testing and improving or developing algorithms to relate optical measurements to warfighter concerns of diver visibility and vulnerability, 2) utilizing small, autonomous sensor suites to provide optical properties for Navy applications, and 3) utilizing maxi-

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sensor packages with state-of-the-art scattering and absorption instrumentation as source data for Navy algorithms and databases.

## **APPROACH**

In support of diver operations in any area of interest, the Navy (via NAVOCEANO) provides optical planning products to support the mission. At present, these products depict estimates of diver visibility in the horizontal (addressing the issue of how far they will be able to see) and the vertical (addressing the issue of how easily they will be seen, i.e., vulnerability). These products depict either a monthly or seasonal average; however, they are inadequate to support most littoral operations and do not forecast for areas where the optical properties can change over finer scales than modeling and remote imagery reveal. Given recent developments in optical instrumentation and the application of collected data to Navy issues, the technology now exists to provide better estimates of diver visibility and vulnerability. CNMOC established the GLOW project to forward this goal and to identify and mitigate gaps in R&D and transition processes. Preisendorfer algorithms (Duntley, 1952; Preisendorfer 1976, 1986) tested via previous GLOW exercises are currently used by NAVOCEANO to generate diver visibility products. To facilitate further work, the GLOW project teamed with others to form the ORCAS initiative funded under NOPP.

Until recently, optical measurements used to support diver visibility and vulnerability have relied on Secchi-depth values taken from surveys as far back as the 1930's. These data are difficult to use in depicting the strong dynamic nature of the coastal environment where very shallow-water operations occur. With the advent of relatively new instruments such as the absorption-attenuation meter and three-angle scattering sensor (WET Labs, Inc.) and the absorption/attenuation-backscattering instruments (HOBi Labs, Inc.), improved measurements of optical properties are available. Such data do or will populate the optical databases of NAVOCEANO and thus are vital source material for fleet support products. However, the algorithms that derive visibility from optical properties were either formulated prior to the development of these modern in situ instruments, or as in the case of the DiVA (Diver Visibility Algorithm) model, there is concern about the measurement parameters themselves and use of an instrument-specific model. Therefore, the algorithms must be tested in light of these improved measurements to determine if the models of the past are applicable and to determine the optimized products given our improved measurement potential.

Four GLOW experiments have been conducted since it was initiated in 1998, two preceding ORCAS and two since. In all experiments, existing algorithms for diver visibility were applied to field data and then compared to actual visibility as observed by Navy divers. Results of the preliminary GLOW experiments indicate that, indeed, visibility algorithms need to be reviewed and most likely revised (actual diver visibility was underestimated by theory by a factor of 2 to 3). However, there were questions concerning angle of approach, ambient light, and direct light versus scattered light that was visible to the Navy divers. GLOW identified the R&D need to revalidate/revise existing diver visibility algorithms and to standardize the elements of both daytime and nighttime vulnerability. In response to the uncertainty in diver visibility, McBride (unpublished) developed a model that included turbid water backscattering, contrast differences, ambient light, and viewing angle. This model will be transitioned to NAVOCEANO. Also being considered for transition to NAVOCEANO is DiVA, a camera-based visibility algorithm that should be particularly useful for applying data from the new absorption/attenuation-backscattering instruments (both DiVA and instrument, HOBi Labs, Inc.). There is a need to compare the output of the various visibility models and then determine which are most appropriately used in specific warfighter applications. Also to consider is which models offer the

most accurate prediction using the least amount of information. Therefore, selection of the most appropriate model(s) for generating fleet support products may be situation and data dependent.

For both visibility and vulnerability experiments, any available remote ocean color imagery will also be included in the analyses. Although in situ measurements and resultant capabilities are the focus of this work, remote imagery is an important complement for characterizing the synoptic field and for potentially gathering preliminary data in "denied access" regions prior to the covert deployment of an operational ORCAS system in the future. It also allows for the direction of the study into potentially important areas of either high/low visibility and high/low vulnerability.

## **WORK COMPLETED**

During Year One of this grant, experiments were conducted in July 2000 off New Jersey at the Longterm Ecological Observation station in 15 meters of water (LEO-15) in collaboration with the Coastal Ocean Observation Laboratory (COOL). This site was selected for study since contrast targets, an imaging camera, and several profiling optical packages were all being deployed as part of other projects (HYCODE). Navy divers were used to compare observed visibility variability and to test new algorithms (applied to in situ data) using a black and white and a solid black target. Vulnerability tests were also conducted at night and compared to in situ optical and bioluminescence data.

Our objectives were to characterize the local bioluminescence in both turbid and clear waters of LEO-15, to investigate solar angle dependencies on underwater horizontal visibility of black/white and black targets, and to evaluate the visibility of a black target using vertical observations. A profiling package was assembled similar to the Macro profiler (without the nutrients) under development by URI. It included measurements of conductivity, depth, temperature, scattering at three wavelengths and three angles, a nine channel absorption/ attenuation meter, a hundred-channel absorption/ attenuation meter, and the Variable Aperture Beam Attenuation Meter (VABAM). Additionally, since ONR is considering use of the HOBI Labs a-beta and c-beta instruments and the DiVA model, these instruments were added to the profiler. The exercise was divided into day operations the first week and night operations the second week.

For the day operations, targets were deployed at 10 and then at 30 foot depths. Navy divers then approached the black/white or black target from each of four directions relative to the sun's position (toward, away, left perpendicular, right perpendicular). During the runs of the divers, both profiles and time series (at diver depth) of optical properties were collected in as close proximity to the divers as safety allowed (100 feet).

The northern Gulf of Mexico was selected for field work for Year Two of this grant. The area offshore from Pensacola, FL was chosen for two reasons. First it was logistically easier for the Navy divers due to the proximity of Naval Air Station Pensacola and the divers' reserve site at Panama City. But more importantly, it offered a wide dynamic range of conditions from dirty, coastal waters of the Mississippi Sound to the clean waters of the loop current. The western Gulf also has a "dead" zone where anoxic conditions and optical layering can be persistent during the summer and fall months. The impacts of these optical layers on underwater visibility are not well understood, thus warranting further investigation.

ORCAS tests were conducted by project partners (P. Donaghay, URI, lead) and are described in detail in the associated ORCAS report. The GLOW experiments for diver visibility and vulnerability took place concurrently with the ORCAS testing. NAVOCEANO committed fifteen days of shiptime of the RV Longhorn (13-28 Sept 2001) in support of this effort. Also during this experiment, NRL deployed its optical package that has several WET Labs attenuation/ scattering sensors (already used by NAVOCEANO), and HOBI Labs a-beta and c-beta instruments into the maxi-sensor. These exercises were designed to test revised new visibility algorithms available to the fleet (McBride, Maffione) and to test the availability of input parameters for these models.

For the GLOW IV experiments, the target rigging was set up in an L-shaped orientation. The target's tether had securing points at 10 and 30 feet below the surface buoy at each of the three moorings for setting the various targets at fixed depths relative to the surface. Two sets of three targets were used for the diver visibility measurements. The targets were near neutrally buoyant spheres (~20 inch diameter) in two different color/pattern schemes. One set of targets was painted solid black, and the other, high contrast (black/white).

Horizontal visibility observations were conducted as they were during GLOW III at Leo-15. Directionality as East-West, West-East, North-South, and South-North was assessed with at least four repetitions. Observation depths were 10 and 30 feet. Bottom depth was approximately 46 feet. The spherical targets were used for this experiment. Concurrent in situ optical data were obtained via the NRL packages in close but safe proximity to the diving operations. Several visibility data sets were also acquired with concomitant ORCAS data.

Specially-designed contrast panels were also sighted. Starting at one end of the L-rigging, the divers used a camera to take a high-resolution still shot of the panel when all the lines can be clearly seen (entire panel in field-of view). Video was taken at the same time as the still shots. The diver would back away from the panel, stopping at increments, taking both a still shot and video of the panel. A third diver marked the distance at which the largest bars (marked as '32' on the panel meaning 32 mm per black/white pair) on the panel could no longer be distinguished. The diver with unaided visibility indicated his inability to distinguish the separation of bars by holding up two fingers in the line of the video shot. No underwater flash, artificial lighting, or filters was used for the panel experiments. The panel operations were conducted at one depth. Air shots of the panels and targets (black and black/white spheres) were taken for calibration purposes.

Vertical vulnerability was assessed during daylight hours only. A target was lowered over the side of the R/V Longhorn to a predetermined depth using one of the marked distance lines. The depth at which the target disappeared was noted. With a masked swimmer at the water's surface and a surface observer on the R/V Longhorn, both looking down into the water column, the target was then slowly raised. Both the swimmer and surface observer recorded the distance from the target that it was first discernable. The above procedure was repeated at intervals through out the exercise.

## **RESULTS**

For the GLOW IV experiment off Pensacola, initial evaluation of the diver visibility data corroborates earlier data from previous GLOW experiments. These data show that the standard hydrologic range algorithm underestimates underwater visibility detection ranges. The data also reveal the extent to which sun azimuth angle relative to viewing direction affects underwater visibility detection ranges.

This corroboration was critically necessary for two reasons: to develop improved models that include affects of different water types and to increase the amount of existing data for diver visibility since operations were hampered at the GLOW III experiment conducted at LEO-15 due to various factors. The most notable of these improvements were as follows.

- 1) Weather: the weather was suitable for diver operations on all test days as opposed to the last experiment where weather and at-sea conditions either kept our dive team out of the water or impacted their activities.
- 2) Target field deployment: When the dive team could work at the GLOW III test site, it was hampered by having to deploy/recover the target field every day. At GLOW IV, the target field could be left intact for the duration of the experiment.
- 3) Target design: The divers stated that the redesign of the spherical visibility targets (lighter and neutrally buoyant) was critical to more efficient data collection. Previously, the targets needed weighting to counter their buoyancy and were very heavy and cumbersome in and out of the water.
- 4) Experience: the Navy divers were familiar with the objectives and methods of the experiment.

During this most recent experiment, the GLOW team recorded approximately five times the amount of diver visibility range data collected during the previous GLOW III experiment. Additionally, we were able to collect contrast transfer function data with our contrast panel targets that we were unable to collect at the New Jersey site because of high current velocities at the test site and camera problems.

Over the course of the experiment, we experienced one failure of the CTD unit on the optical profiling package. Fortunately, it was quickly initiated repaired and the unit was again operational with no loss of data.

## **IMPACT/APPLICATIONS**

The impact of the directionality on diver visibility is important since neither the existing visibility nor the proposed DiVA models take this dependency into account in the visibility calculations. The 30% deviation can mean the difference of identifying a mine at 14 feet or getting closer than 10 feet. This has a direct consequence to tactical situations and stand-off distances used by Explosive Ordnance Disposal (EOD) divers. Relationships of vertical optical properties and actual vertical observations of divers and targets have applications to mine countermeasures and special operations. The bioluminescence characterization is important in combination with the optical properties to predict nighttime diver vulnerability.

## **TRANSITIONS**

No transitions have occurred at this stage of the program.

## **RELATED PROJECTS**

Evaluation of the a-Beta Instrument and DiVA Model, ONR Code 32, Alan Weidemann.

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